NMP

NEW MILLENNIUM PROGRAM

Innovative Approaches for Advanced Space Technology Demonstrations

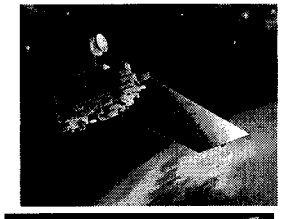
Fuk Li

September 28, 1999

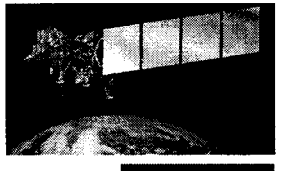
Ambitious Plans

NMP

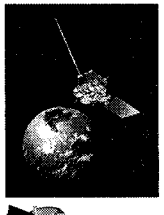
Office of Earth Science



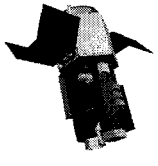
- EOS Post 2002



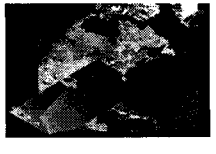
- LandSat Follow-on



- NPOES



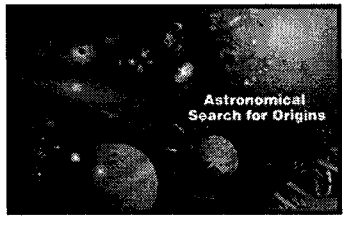
- Advanced Geostationary



- ESSP

Office of Space Sciences

- Mars Exploration
- Outer Planets
- Discovery
- Solar Terrestrial Probes
- UNEX/SMEX/MIDEX
- Gravity Probe B/LISA
- Next Generation Space Telescope
- Space interferometry Mission/Terrestrial Planet Finder



Advanced Technologies:
Essential to Achieve OES and OSS Objectives

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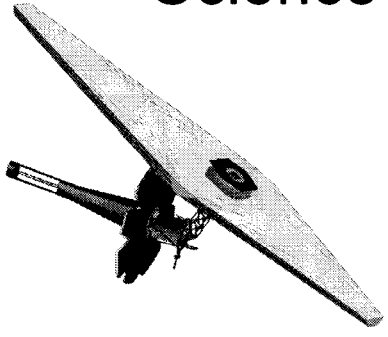
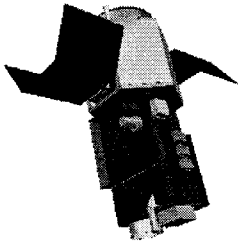
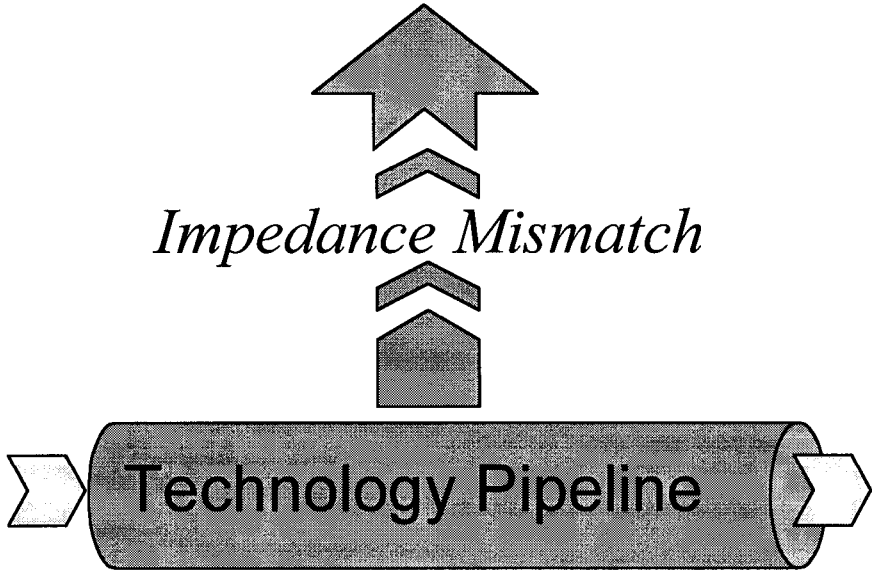
Science Missions







Impediments to Rapid Technology Infusion:

- Lack of flight heritage
  - real or perceived risks
    - cost
    - schedule
    - performance
- Little visibility to mission planners
  - capabilities poorly understood
  - A complete paradigm shift is needed to fully exploit some technologies

The New Millennium Program

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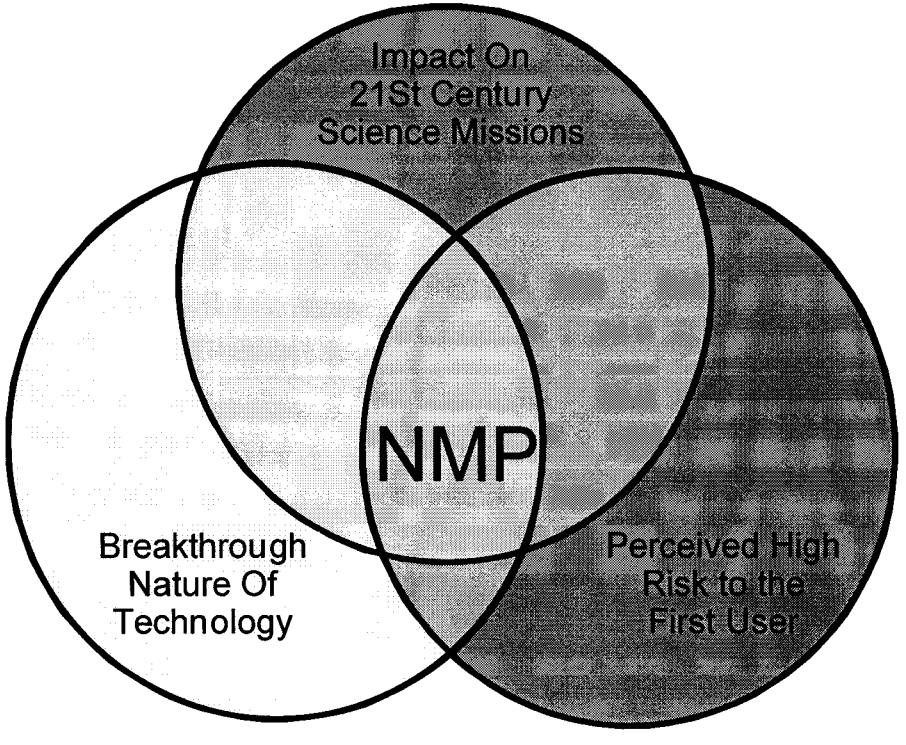
A cross-Enterprise program to identify and flight validate breakthrough technologies that will significantly benefit future Space Science and Earth Science missions



- Breakthrough technologies
  - Enable new capabilities to meet Earth and Space Science needs
  - Reduce costs of future missions
- Flight validation
  - mitigates risks to first users
  - enables rapid technology infusion into future missions

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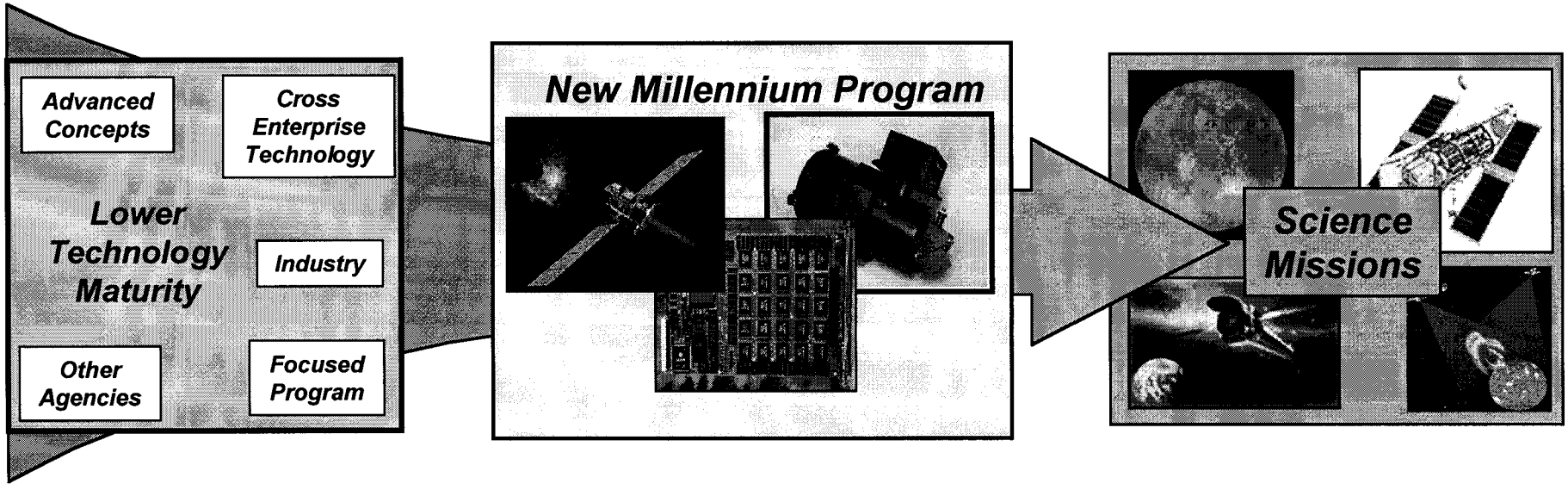
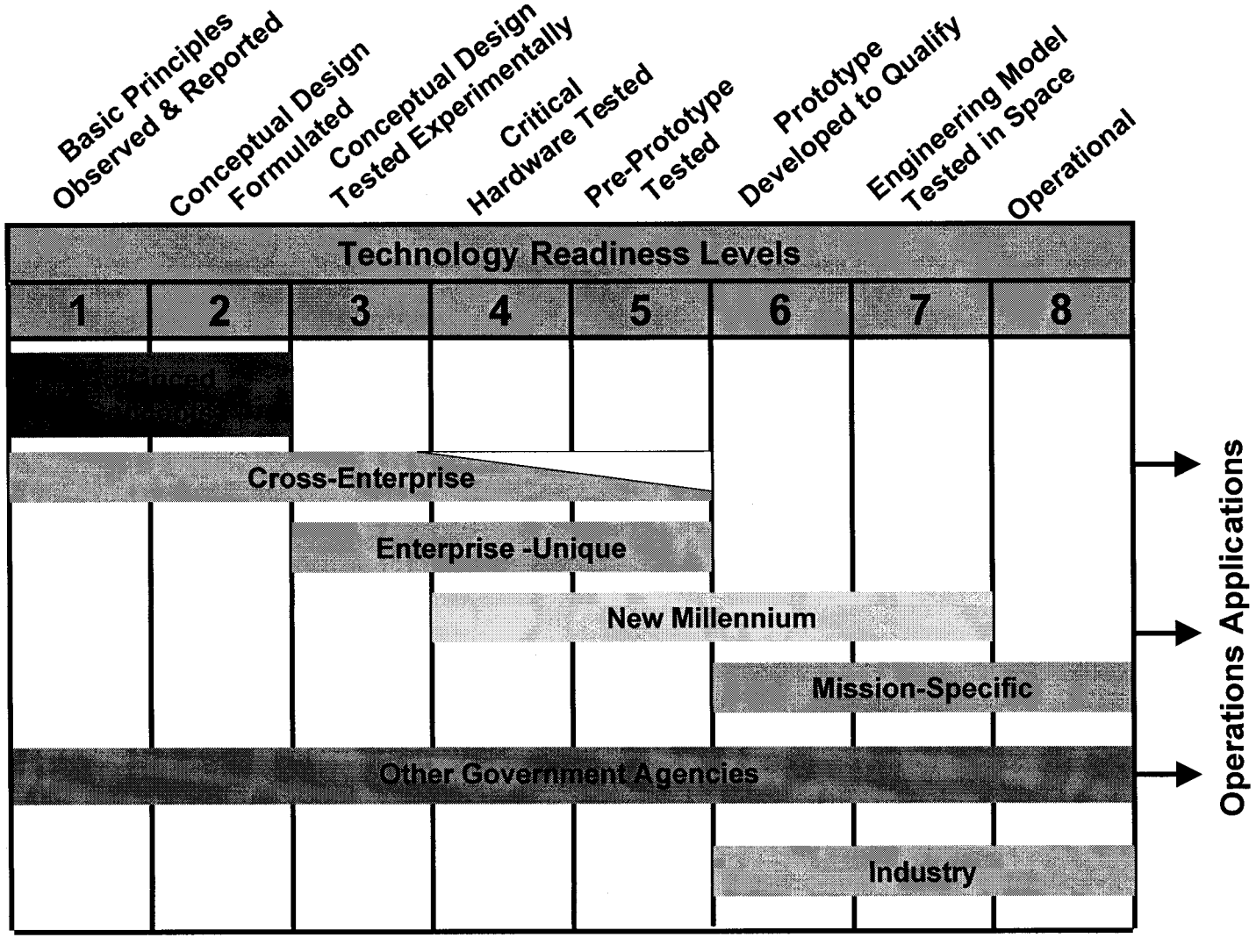
The New Millennium Program Fills a Critical Role in Space Science Technology Development



Role of NMP in Technology Development



Space Science Strategic Plans Drive the Technology Validation Needs

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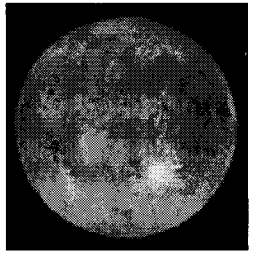
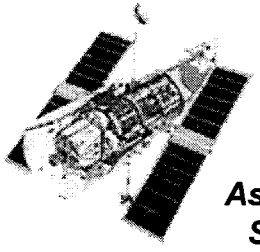
Strategic Plans /Technology Roadmaps

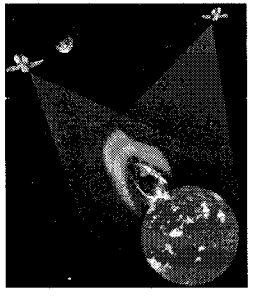


Solar System Exploration (SSE)



Astronomical Search for Origins (ASO)

Structure & Evolution of the Universe (SEU)



Sun Earth Connection (SEC)

Future Missions Technology Needs

Space Science Technology Development Needs

Technology Development/ Availability

TECHNOLOGY PIPELINE

Cross-Enterprise Technology Thrust Areas

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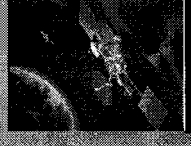
Office of Earth Science

Office of Space Sciences

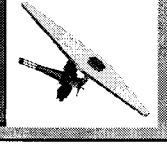


Thinking Space Systems

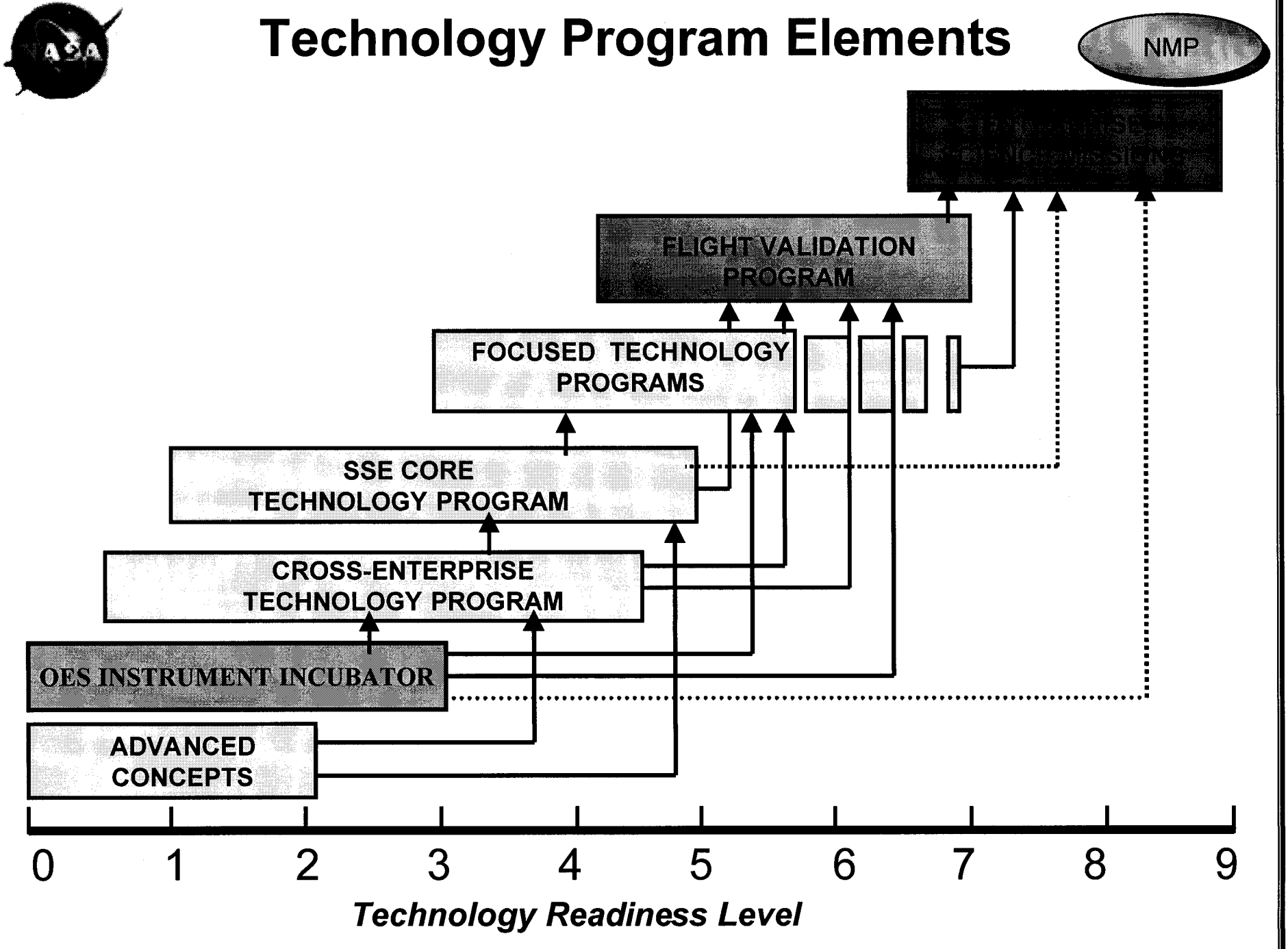
Micro-Nano Sciencecraft

Distributed Spacecraft

Ultra-Lightweight Structures / Space Observatories



Technology Program Elements



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Validation Flight Launch Schedule

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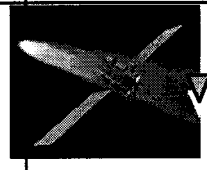
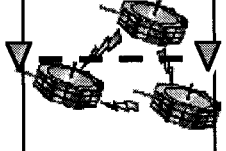
Year	98	99	00	01	02	03	04
DS1		▽ 10/98					
DS2		▽ 01/99					
EO1			▽ 12/99				
Future Flights							
ST3							
ST5							
EO3						▽	▽

Deep Space 1
Rapid Access to Small Bodies

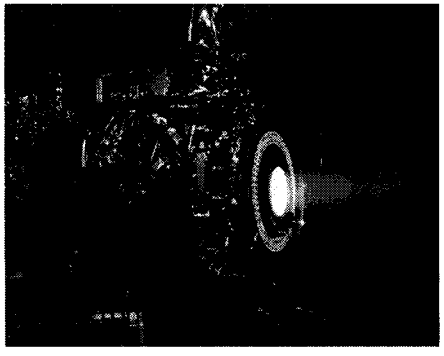
NMP

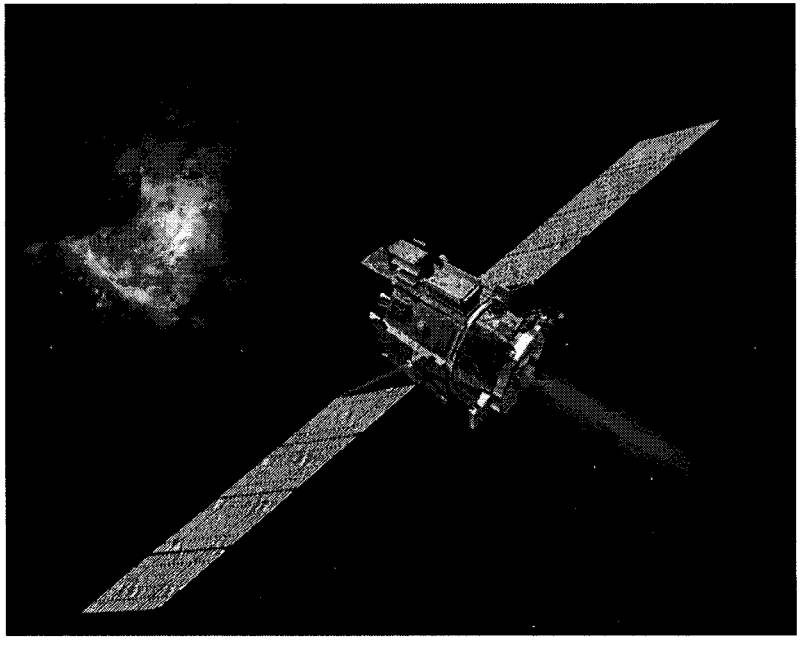
- Designed to validate ion propulsion and 11 other advanced technologies
- Successfully launched, October 24, 1998
- Technology Validation Status
  - all technologies fully validated
- Encountered Asteroid 1992KD on July 29, 1999
  - Significant science and technology return
- Extended mission will allow encounters with 2 comets in 2001:
  - Comet Wilson-Harrington
  - Comet Borelli

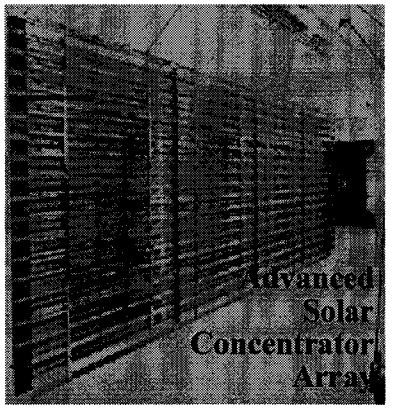
Deep Space 1

System Level Validation of 12 Breakthrough Technologies

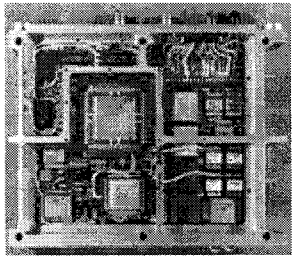
NMP



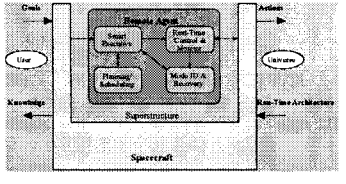


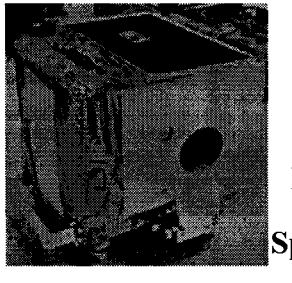


Small Deep Space Transponder



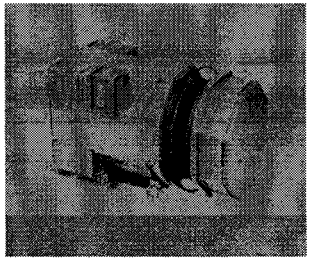
Remote Agent Architecture

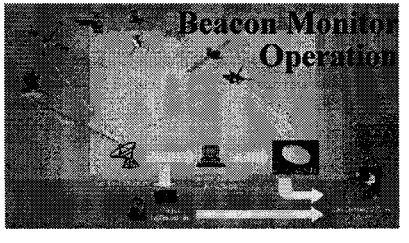


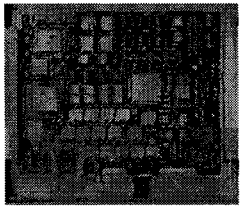


Plasma Experiment for Planetary Exploration

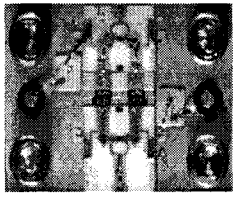
Miniature Integrated Camera Spectrometer





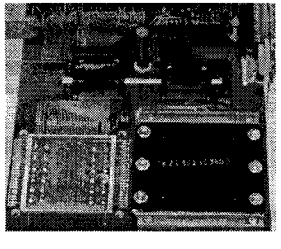


Low Power Electronics

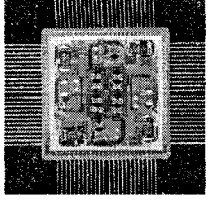


Ka-Band Solid State Power Amplifier

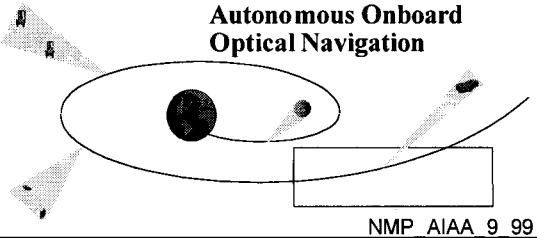
Multifunctional Structure



Power Activation & Switching Module



Autonomous Onboard Optical Navigation



Solar Electric Propulsion Future Users

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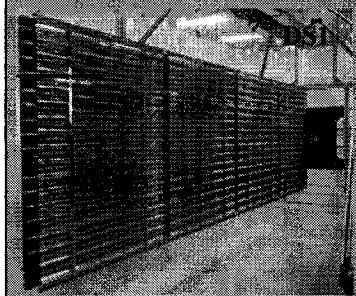
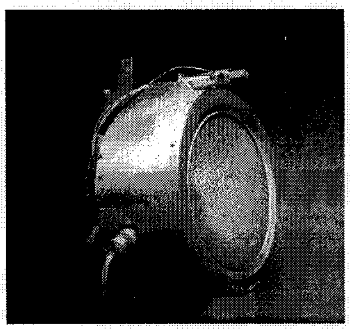


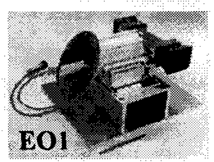
Advanced Solar Concentrator Array

EO-1 Lightweight flexible solar array

Light Weight Solar Arrays



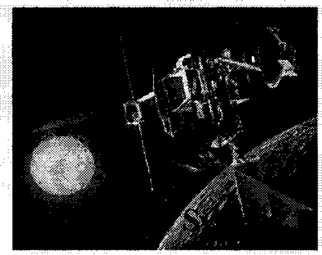
NSTAR Ion Propulsion

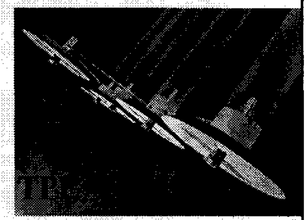


Pulsed Plasma Thruster

Electric Propulsion

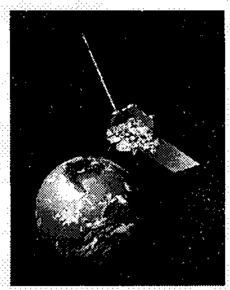
Space Science

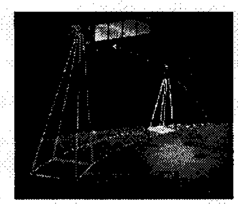




Benefits of Solar Electric Propulsion

- Transportation
- Formation Flying
- Station Keeping/Orbit Maintenance





ESSP

Earth Science

Thinking Spacecraft Future Users

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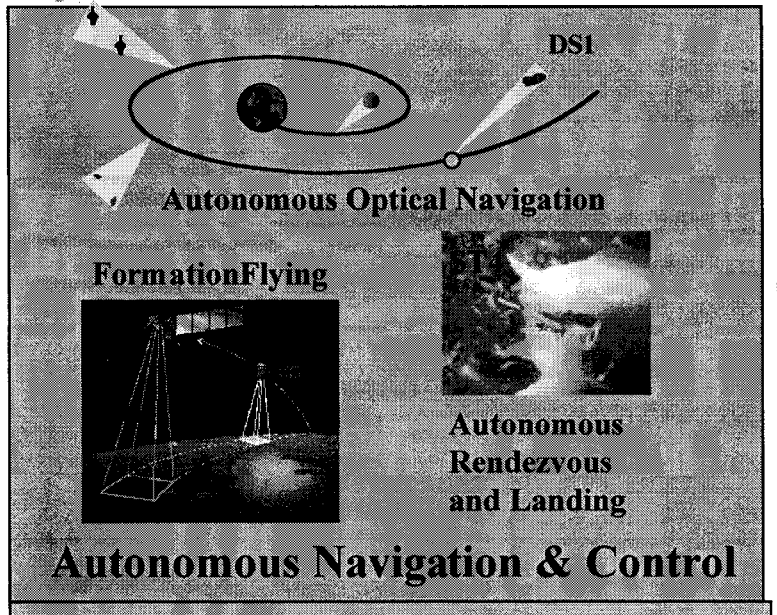
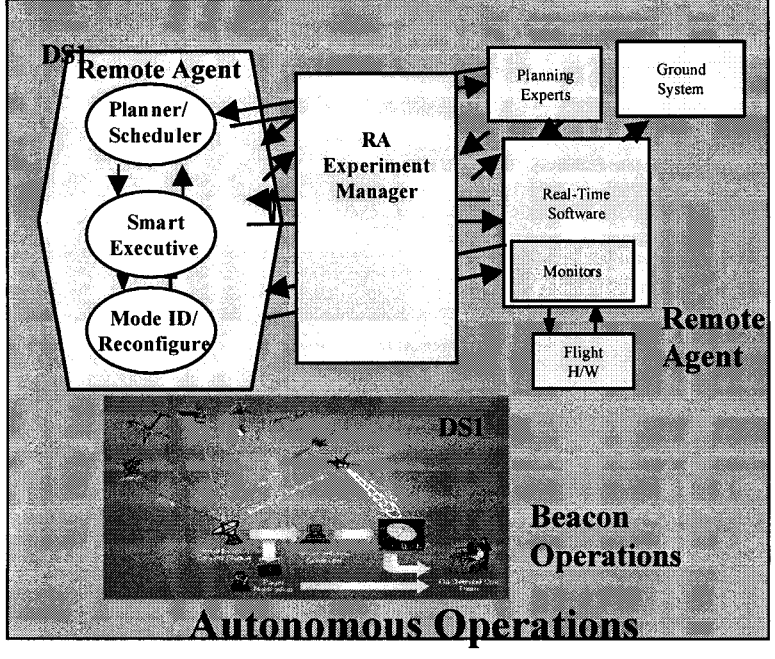
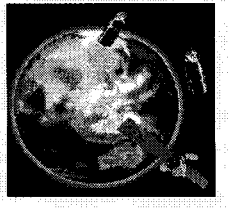
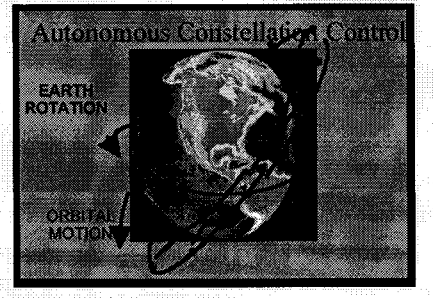




Earth Science

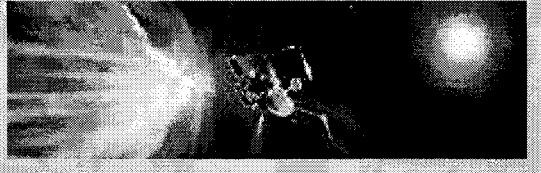




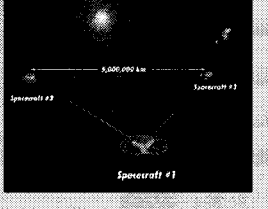
- Formation flying and/or autonomous operations for EOS and ESSP Missions
- Magnetospheric Multiscale, Magnetospheric Constellation
- Self monitoring for Europa Orbiter, MIDEX proposals & Earth orbiters

Space Science

- Autonomous optical navigation for Stardust, and Europa Orbiter



- Automatic sequencing & real time control for interferometer instruments such as TPF and LISA



Deep Space 2: Mars Microprobes

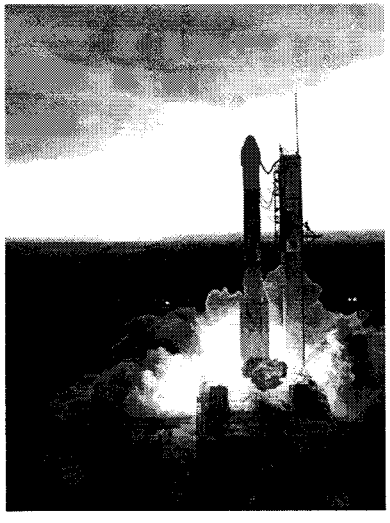
NMP

- Designed to validate technologies for surface penetrators and network science
  - Passive entry, descent, and landing system
    - built to survive high-g impact (30,000 - 80,000 g's)
  - Miniaturized Electronics
    - power, microprocessor, telecom
  - Low-temperature batteries
  - Soil acquisition/Water detection experiment
- 2 probes successfully launched, January 3, 1999
  - Piggyback on Mars Surveyor 98 Lander cruise stage
- Landing in Martian South polar regions
  - December 3, 1999
  - Validation data expected after landing

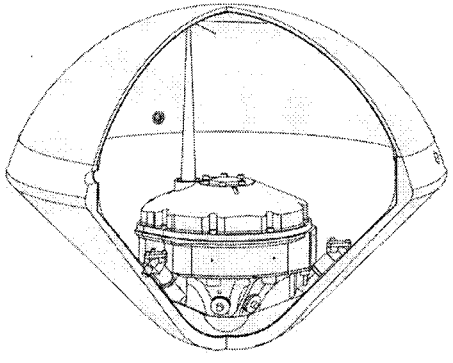
Deep Space 2

NMP

Technologies for surface penetrators and network science

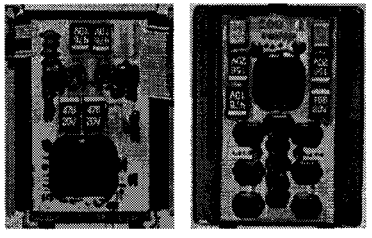


Launch:
January 3, 1999

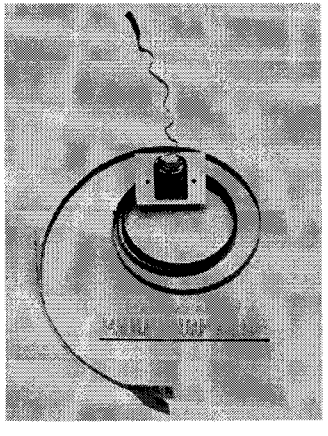


Single-Stage, Passive Aeroshell Entry System

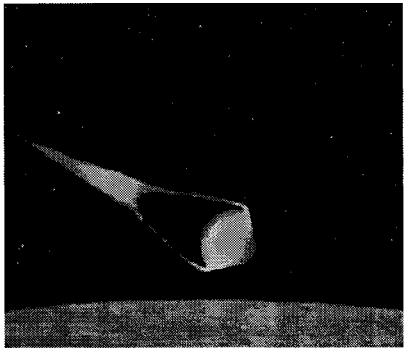
Power Microelectronics



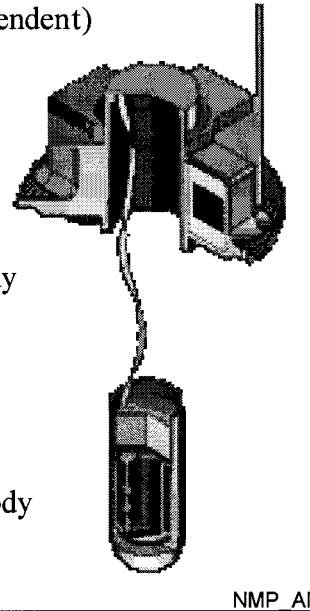
Flexible Interconnect

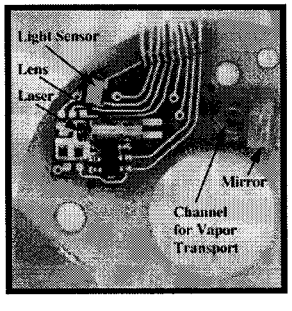


Probe Entry
December 3, 1999

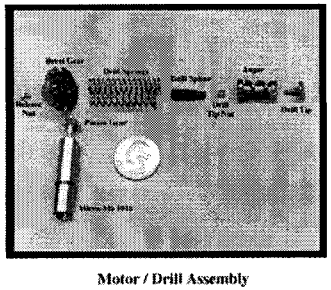


Landed Operations:
Primary Mission: 2 Sols
(extended mission battery dependent)





Miniaturized Tunable Diode Laser Spectrometer
Subsurface Water Detection

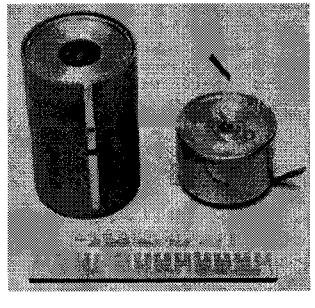


Motor / Drill Assembly

Drill and Soil Acquisition System

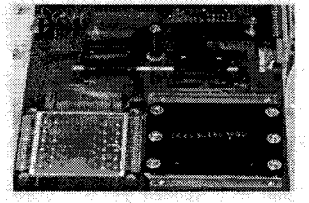
Advanced Microcontroller

Lithium Ion Batteries

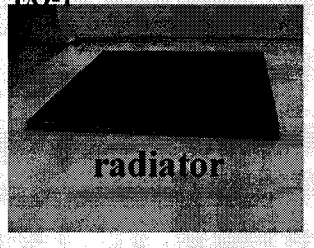


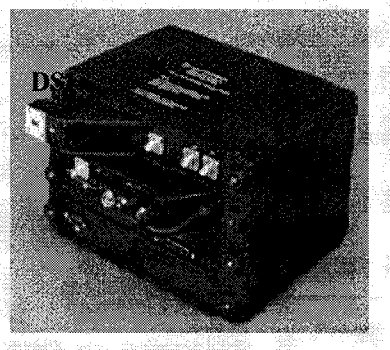
Micro-Nano Spacecraft's Future Users

NMP



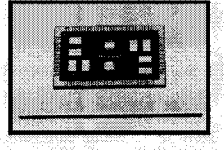
Multifunctional structure





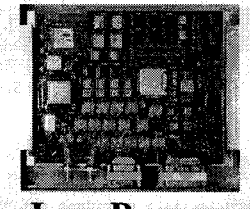
Small Deep Space Transponder

DS2



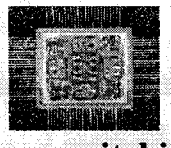
Advanced Micro Controller

DS1



Low Power Electronics

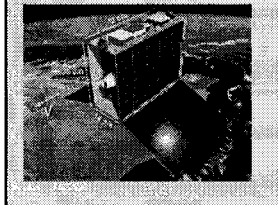
DS1

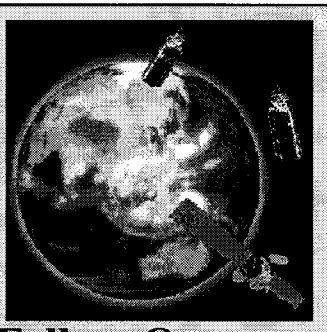


Power switching module

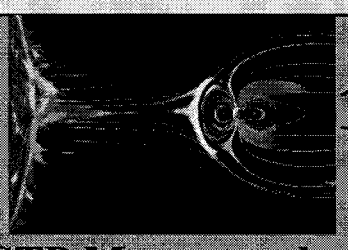
Innovations that simplify design, fabrication, reduces mass & reduce resource requirements

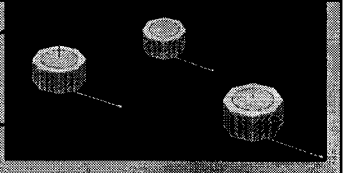
Earth Science



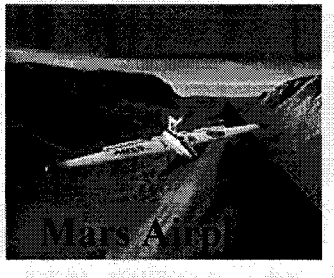


- Potential for EOS Follow-On
- ESSP and Earth Probes



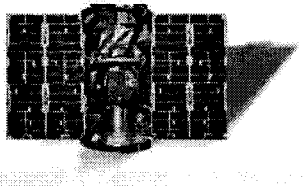


- STP Magnetospheric Multiscale Mission



DISCOVERY

SMEX



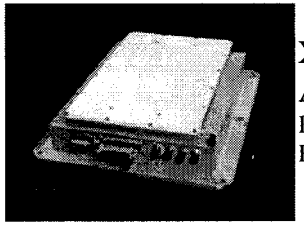
- Mars Micro missions
- Discovery
- UNEX/SMEX/MIDEX

Space Science

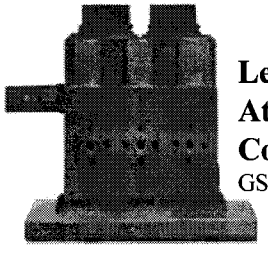
Earth Observer 1

Validation of 9 Breakthrough Technologies

NMP



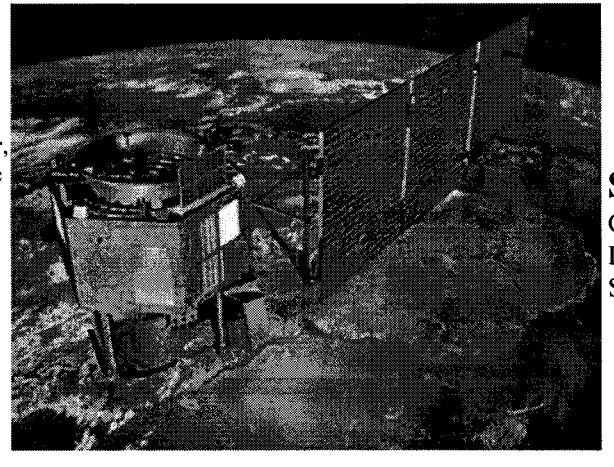
X-Band Phased Array Antenna:
Boeing, GSFC & Lewis Research Center



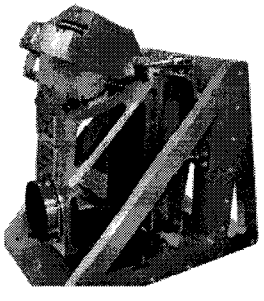
Leisa Atmospheric Corrector:
GSFC

Advanced Land Imager:
MIT Lincoln Lab, GSFC, Raytheon / Santa Barbara Remote Sensing, & Sensor Systems Group

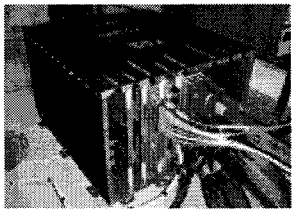
Carbon-Carbon Radiator:
Air Force Research Lab, Amoco Polymers, BF Goodrich, GSFC, Langley Research Center, Lockheed Martin, Naval Surface Warfare Center, & TRW



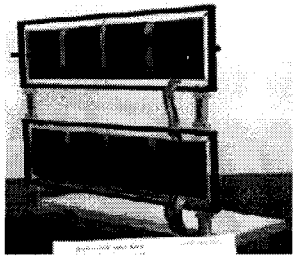
Spacecraft
GSFC, Litton, SWALES



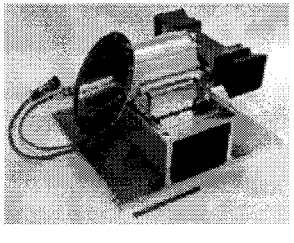
Hyperion:
TRW, JPL, GSFC



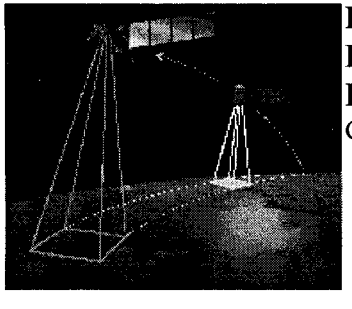
Wideband Advanced Recorder Processor:
GSFC, Litton, MIT Lincoln Lab, Swales, & TRW



Lightweight Flexible Solar Array:
GSFC, Lockheed Martin, & Phillips Lab



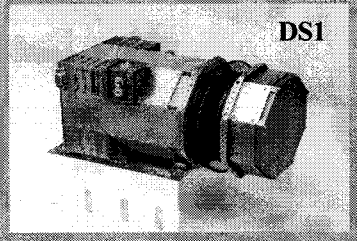
Pulsed Plasma Thruster:
GSFC, Lewis Research Center & PRIMEX



Enhanced Formation Flying
GSFC, JPL

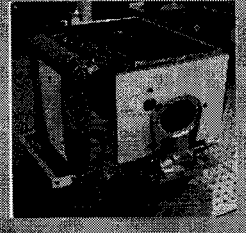
Hyper/Multi-Spectral Imagers & Spectrometers Future Users

NMP

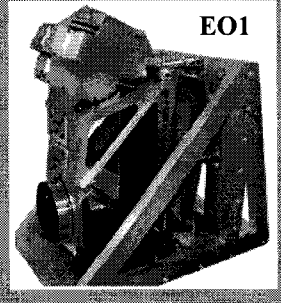


PEPE

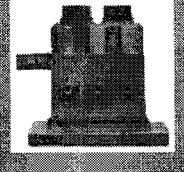
Plasma Spectrometer



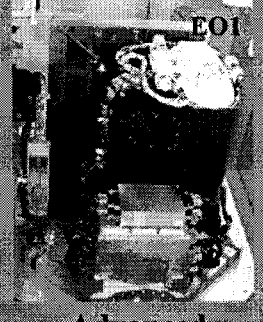
Miniature Integrated Camera Spectrometer



Hyperion



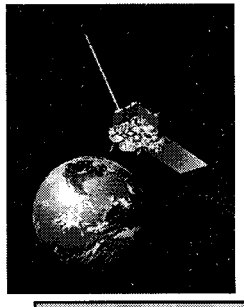
Atmospheric Corrector

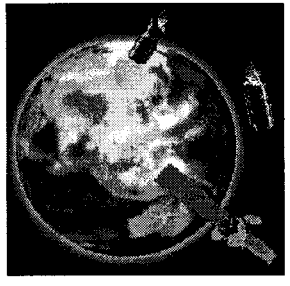


Advanced Land Imager

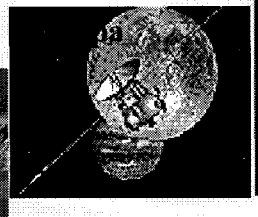
Hyper/Multi-Spectral Imager & Camera-Spectrometer

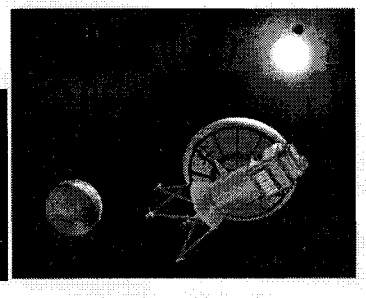
Earth Science





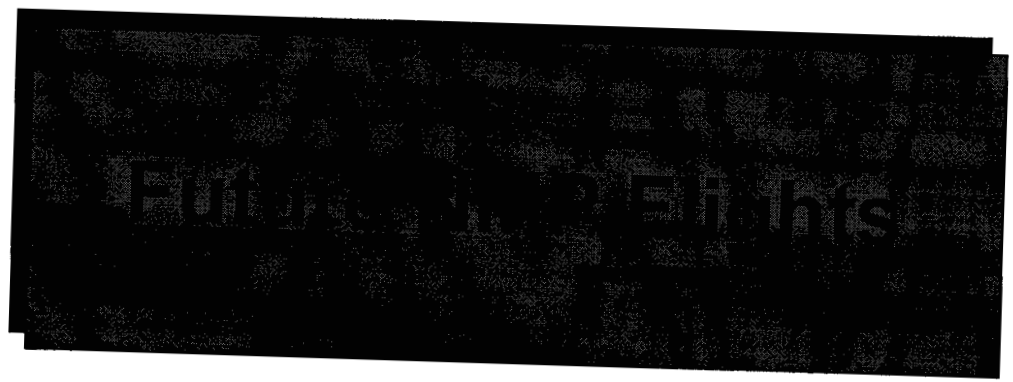
- Planetary & solar plasma scientists have proposed to use copies of the PEPE instrument for future missions
- Validation of an all SiC optical instrument covering the FUV to SWIR will enable many new miniature, low-mass cameras and spectrometers



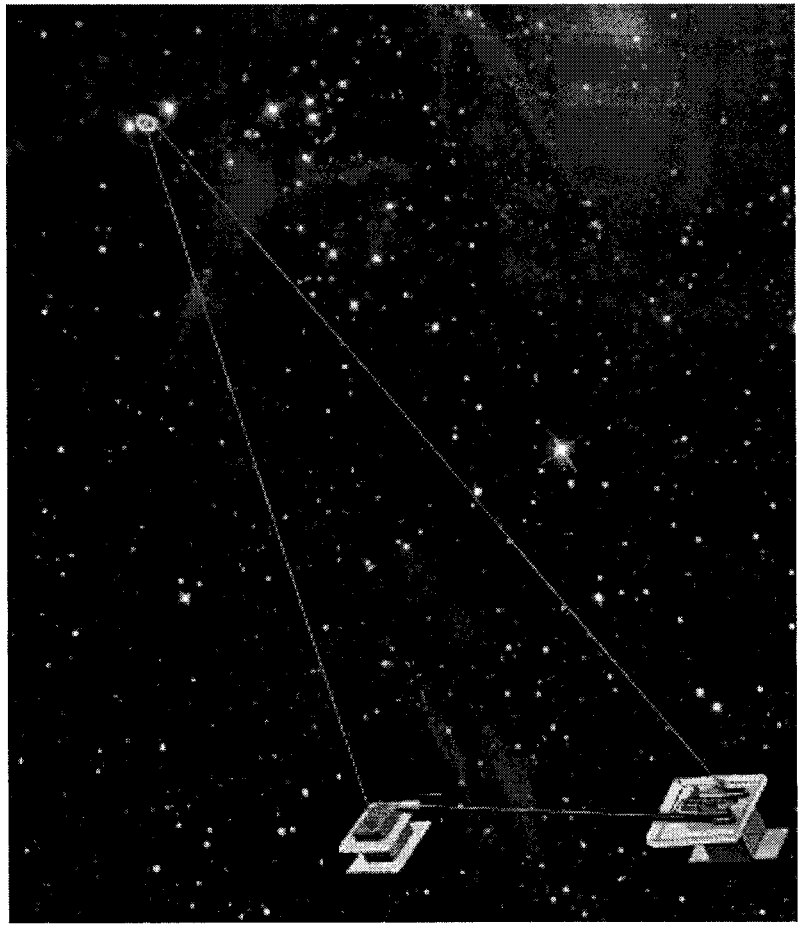


Space Science

NMP



ST3: Two Spacecraft Interferometer



- S/C separation from 50 m to 1 km
  - Observation baselines of 40 to 200 m
  - 8th magnitude stellar targets
- Parabola is locus of constant delay
- Combiner contains 20 m fixed delay line
- Combiner can operate as a 1 m monolithic interferometer
  - No collector, bypass fixed delay
- Both S/C maintain fixed orientation relative to each other during baseline changes

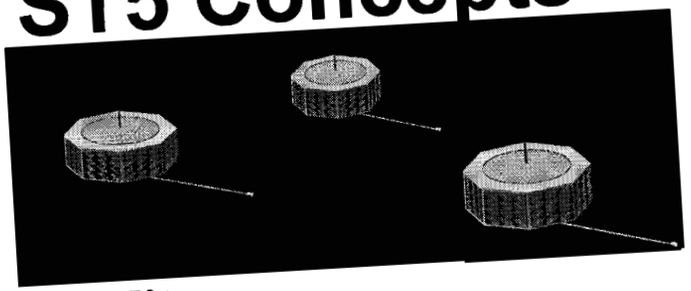
The ST5 Opportunity

NMP

- ST5 will validate technologies for
  - Structure and Evolution of the Universe (SEU)
  - Sun-Earth Connection (SEC)
- Current technology themes
  - Disturbance reduction system technologies (e.g. LISA)
  - Solar sail (e.g., sun polar orbiter, interstellar probe, etc)
  - Nanosatellite (e.g., magnetospheric constellation, etc.)
- Technology RFP issued, March 1999
  - Successful proposers incorporated into study teams
  - Each team prepares a report for mission selection review
- ST5 is a low-cost validation flight
  - Total implementation phase budget of <$30M

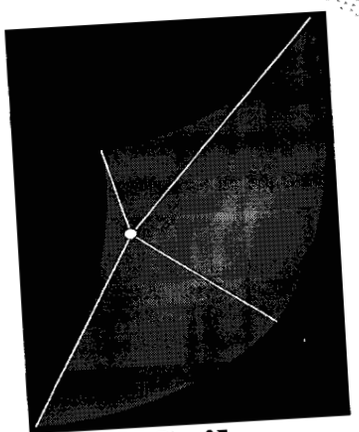
ST5 Concepts

NMP



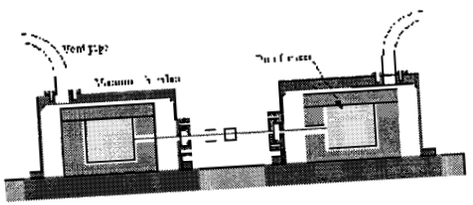
Nanosatellites

- Small (spinning) spacecraft, deployed and operated in constellations
- Each with multiple small Fields and Particles Instrument Technologies



Solar Sail

- Propulsion system to place spacecraft in desired locations unreachable (or un-maintainable) by alternative propulsion systems
- Small Fields and Particles Instrument Technologies (on bus, sail or sub-sat.)



Disturbance Reduction System

- Inertial and position sensing technologies for precision spacecraft positioning - for future gravitational and interferometric applications

ST5 Nanosat Constellation Trailblazer Mission

NMP

Miniature Spacecraft

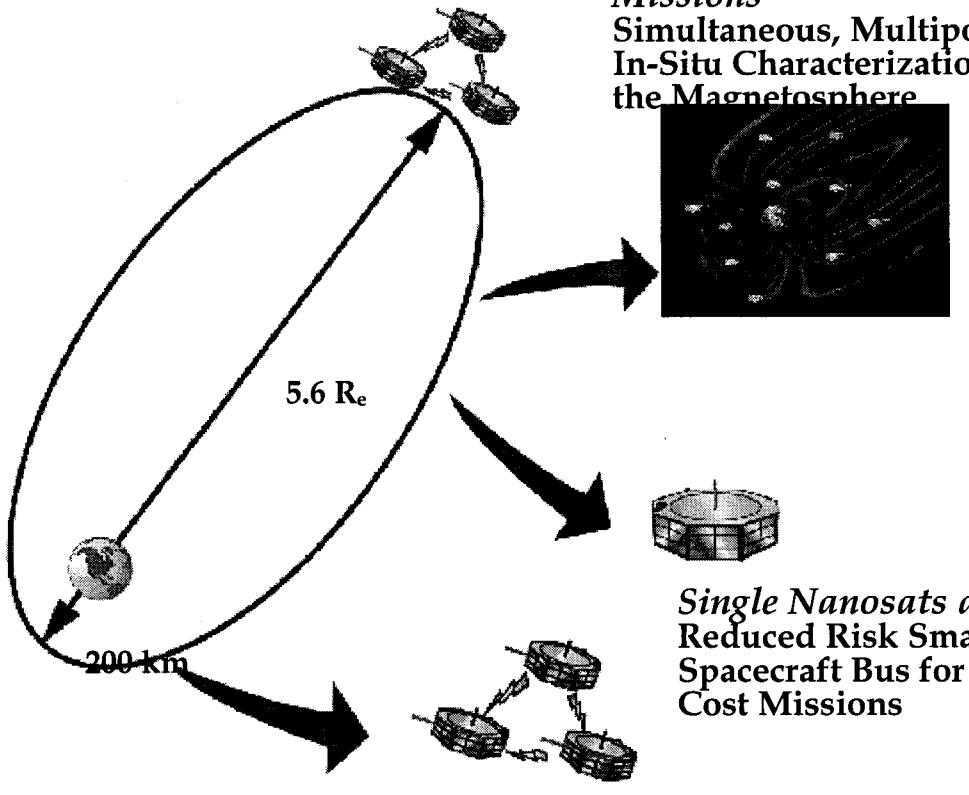
- Systems Design Integration and Test Technologies

Candidate Spacecraft Technologies

- 5V bus - 1/4V logic
- Li-Ion batteries
- Miniature transponder
- Miniature Thrusters
- Multi-functional structure
- Variable emittance coatings

Constellation Control, Coordination, and Operations Architecture

- Ground system autonomy
- Relative ranging
- Intra-constellation communications



Constellation Class Missions
Simultaneous, Multipoint, In-Situ Characterization of the Magnetosphere

Single Nanosats and Probes
Reduced Risk Small Spacecraft Bus for Low Cost Missions

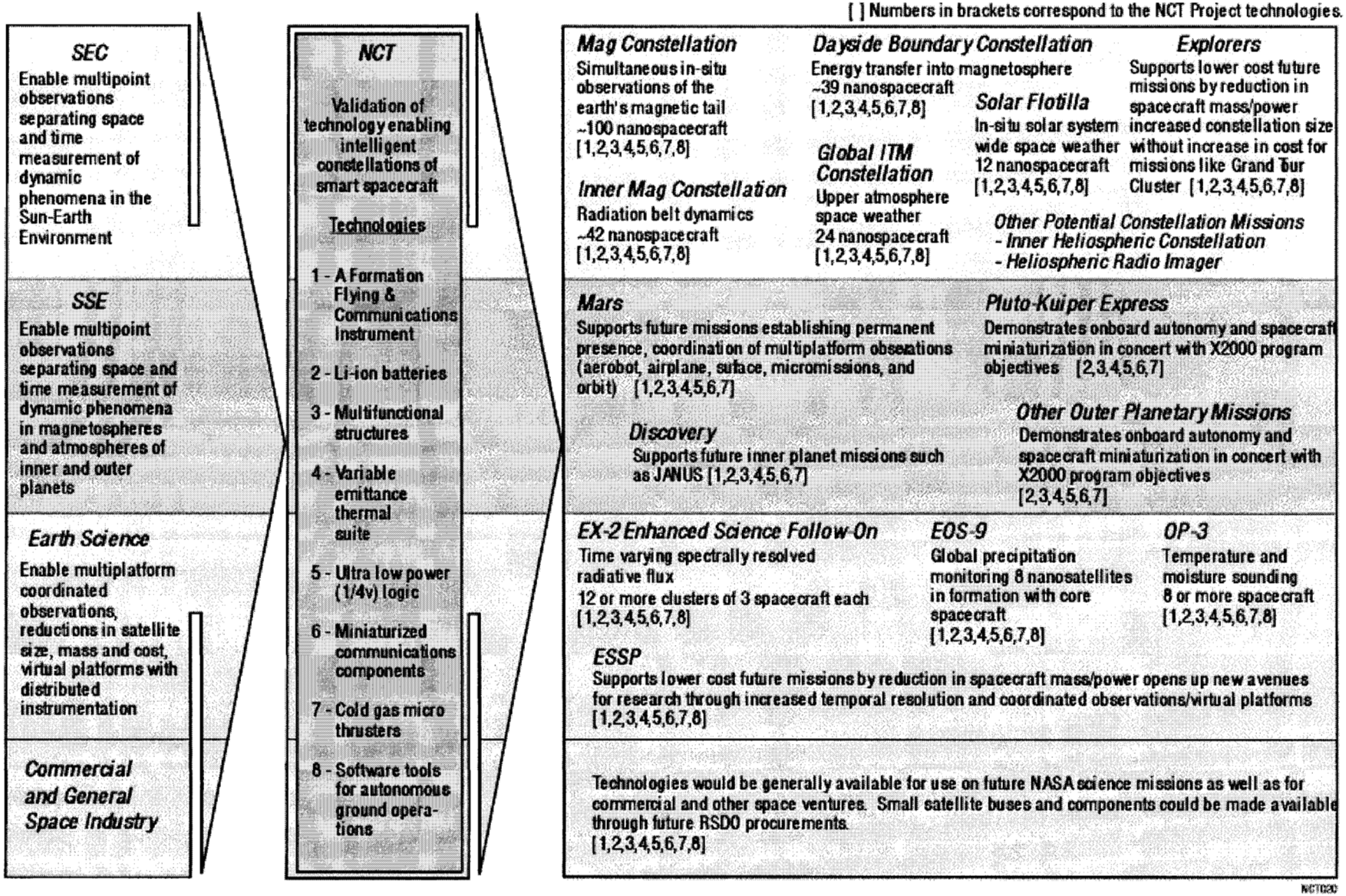
Virtual Platforms
For Science Missions

TECHNOLOGY ⇒ **VALIDATION** ⇒ **INFUSION**

Technology Infusion from ST5 into Future Missions

NMP

[ ] Numbers in brackets correspond to the NCT Project technologies.



NCT020

The EO3 Opportunity

NMP

The NASA OES directed the NMP to:

- Focus the third Earth Observing mission, EO3, on innovative measurement concepts for remote sensing observations from orbits beyond conventional low-Earth orbit (LEO)
  - Geostationary orbits
  - Highly elliptical orbits
  - Mid-Earth and high-Earth orbits
  - L1 and L2
- Issued a NASA Research Announcement (NRA) to solicit the measurement concepts
  - Maximize participation by the Earth science and technology communities
  - identify revolutionary technologies, and/or measurement strategies
- 24 proposals were submitted and peer reviewed by the OES
- 4 concepts were selected for a 6-month study
  - downselected to one or two flight projects before 9/30/99

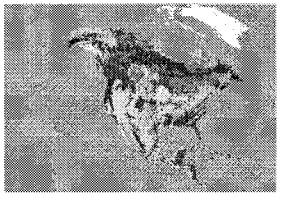
EO3 Measurement Concepts

NMP

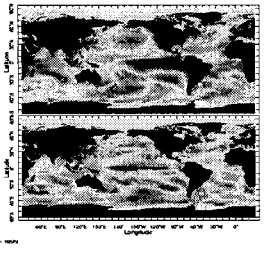
Four Measurement Concepts were chosen for further study as candidates for EO-3 mission

Geostationary Imaging Fourier Transform Spectrometer
Dr. William L. Smith, LaRC

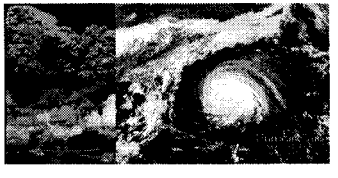
Active Large Aperture Optical Systems for High Resolution Thermal Imaging from Geosynchronous Orbit
Del Jenstrom, GSFC



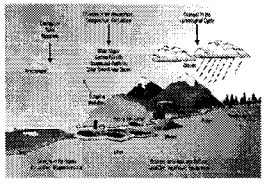
Land-Cover and Land-Use Change



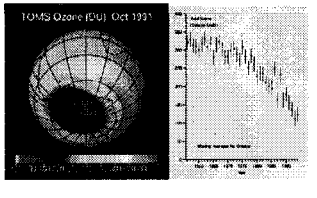
Seasonal-to-Interannual Climate Variability and Prediction



Natural Hazards Research and Applications



Long-Term Climate: Natural Variability and Change Research



Atmospheric Ozone Research

NMP

Validation of the Foundation Technology Selection Process

Technology-focused NMP Process

NMP

- Alignment with Science theme need insured by
  - selecting technologies to address specific capability needs in science roadmaps
  - involvement of science community in identification, review and where appropriate, validation of technologies
- Phase A Concept Definition is technology focused
  - Open, peer-reviewed competition for technologies
  - For system validation, science AO in Phase B where appropriate
  - Provide capabilities needed to enable future high-priority science missions
  - Provide significant improvements in performance, or reductions in life-cycle cost
  - Require validation to mitigate risks to first science user
  - selected technologists participate in project concept definition team
- Independent review of project concepts prior to selection

Key Participants in NMP Process

NMP

Science Community

- Defines capability needs in theme roadmaps
- Participates with NMP to identify technology requirements, review technology candidates / concept studies, and participates via AO where appropriate

NASA HQ

- Defines priorities and constraints for Projects
- Authorizes project concept definition studies
- Leads peer reviews of technology solicitation
- Assigns project implementation center
- Conducts independent reviews
- Selects and approves project for implementation
- Where appropriate, selects science support via AO

NMP

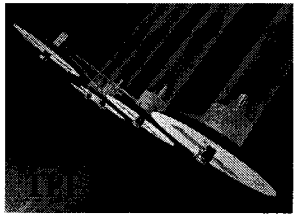
- Leads identification of technology validation candidates
- Conducts project concept definition studies
- Selects technology providers through open competition
- Oversees project implementation

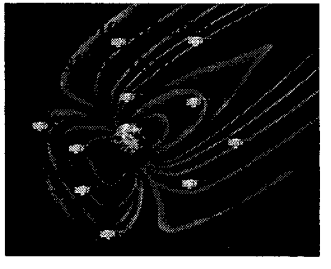
NMP

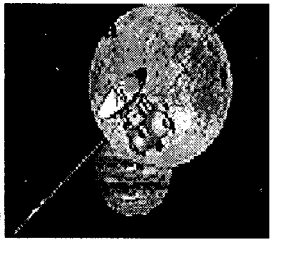
Benefits of NMP Processes

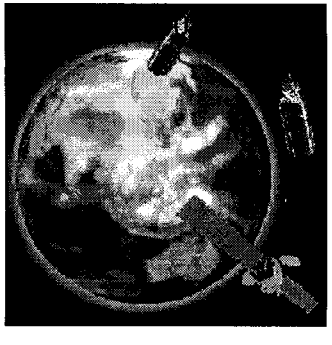
NMP

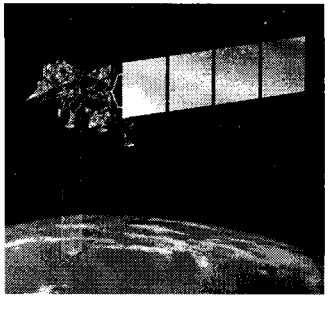
- Infusion into future science missions
  - Future projects using NMP validated technologies
  - Technology database for PI missions
    - New capabilities enable new opportunities
    - MIDEX/SMEX/Discovery/ESSP
- Enhanced NASA's technology community through partnerships
  - Industry
  - Academia
  - Government Laboratories

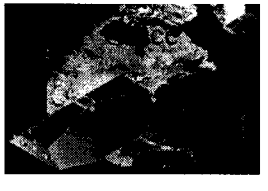


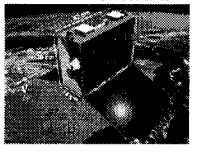


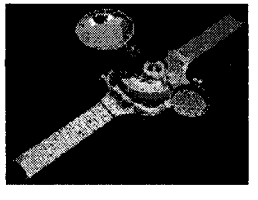


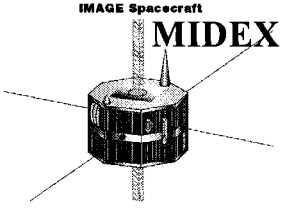


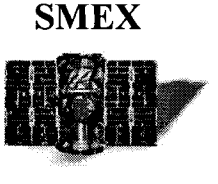








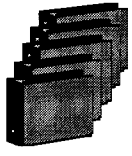




Technology Validation Information Dissemination Activities

NMP

Web



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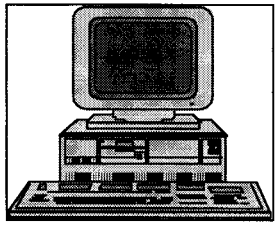
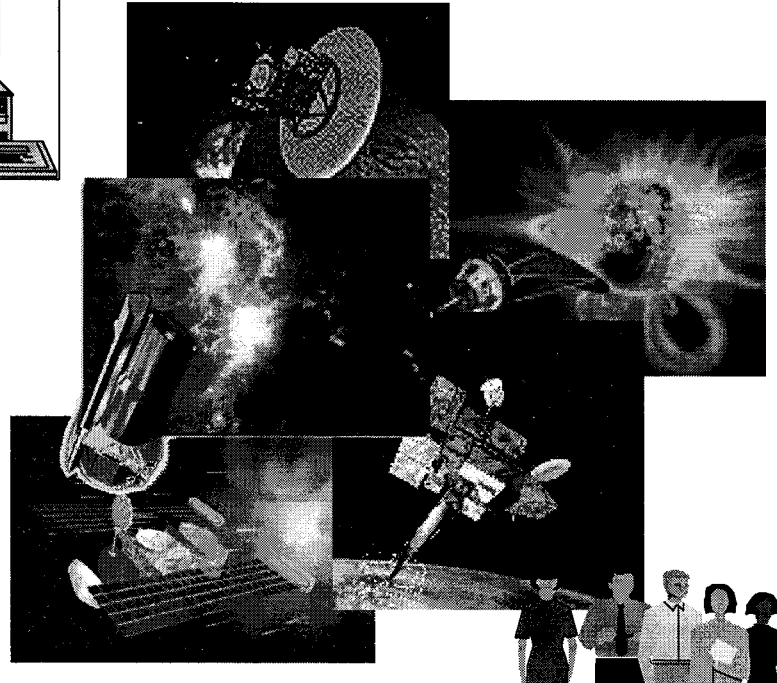
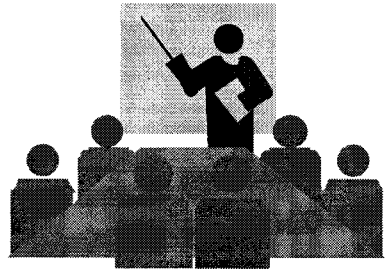
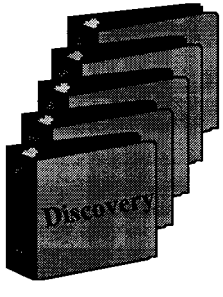


Validation Reports



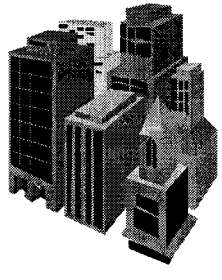


Validation Workshops



Support next set of Science AO's

User Community Contacts



Conferences

Summary

NMP

- NMP space flight validation provides a critical bridge from technology development to use in future science missions
  - Facilitates realization of benefits from NASA technology investment portfolio
- Program focus is on validating breakthrough technologies that enable new high priority science capabilities or provide needed capabilities at greatly reduced cost and risk for both OSS and OES missions
- Breakthrough technologies in each project are classified as project-defining or project-enhancing
  - Project-defining technologies replace proven technologies whose successful operation is required for project success
  - Project-enhancing technologies contribute to increased project capability, but are not needed for project success